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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report summarizes a conference held in Amherst, MA in August 1990. The conference brought together investigators interested in a number of topics relevant to eye movements and visual cognition. Papers were presented on the following topics: (1) Programming saccades, (2) Visual Search and Integration, (3) Scene Perception, (4) Reading, and (5) Reading and Pictures. The conference was very stimulating, the talks were excellent, and the participants agreed that the meeting was very worthwhile. An edited volume will appear in 1992 with the conference papers.					
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EYE MOVEMENTS AND VISUAL COGNITION CONFERENCE

GENERAL INFORMATION

Welcome to Amherst. This folder contains information about the conference. All of the activities for the conference will be held in this building. Breakfast will be served in Room 1001 beginning at 8:00 in the morning on Thursday and Friday and at 7:45 on Saturday morning. The breakfast is buffet style so if you come a bit later, there should still be plenty of food. You should try to get there by 8:15. Lunch and dinner will be in the same room.

The meeting will be held in the Music/Reading Room on the concourse level of this building (push 2 in the elevator). The room is directly across from a cafeteria called the Blueroom. When you get off of the elevator, turn right and the meeting room is on the far left. The meeting will begin at 9:00 on Thursday and Friday and at 8:30 on Saturday.

This packet also contains an abbreviated schedule of the talks, as well as Abstracts for each talk in each session.

The Conference is sponsored by
The Life Sciences Directorate
The Air Force Office of Scientific Research

A-1

EYE MOVEMENTS AND VISUAL COGNITION CONFERENCE

ABBREVIATED SCHEDULE OF TALKS

AUGUST 16, 1990

9:00 - 9:15 Keith Rayner
SESSION 1: Programming Saccades
9:15 - 10:00 John Findlay
10:10 - 10:30 Morning Break
10:30 - 11:15 Burkhart Fischer
11:25 - 12:10 Ray Klein
12:20 - 1:20 LUNCH
1:20 - 2:05 Richard Abrams
2:15 - 2:45 Anne Sereno

SESSION 2: Visual Search and Integration

2:45 - 3:25 Wolfgang Prinz
3:35 - 3:50 Break
3:50 - 4:30 Mary Hayhoe
4:30 - 5:15 David Irwin
6:30 DINNER

AUGUST 17, 1990

9:00 - 9:45 Alexander Pollatsek
9:55 - 10:25 Donald Fisher
10:25 - 10:45 Morning Break

SESSION 3: Scene Perception

10:45 - 11:30 Geoffrey Loftus
11:40 - 12:10 Susan Boyce
12:20 - 1:20 LUNCH
1:20 - 1:50 Peter DeGraef
2:00 - 2:45 John Henderson
2:55 - 3:25 Judy Kroll
3:25 - 3:40 Break

SESSION 4: Reading

3:40 - 4:25 George McConkie
4:35 - 5:05 Sara Sereno
5:15 - 5:45 Robin Morris
6:30 DINNER

AUGUST 18, 1990

8:30 - 9:15 Kevin O'Regan
9:25 - 10:10 Albrecht Inhoff
10:20 - 10:40 Morning Break
10:40 - 11:10 Rene Schmauder

SESSION 5: Reading and Pictures

11:10 - 11:40 Samuel Givens
11:50 - 12:20 Alan Kennedy
12:30 - 1:30 LUNCH
1:30 - 2:10 Charles Clifton
2:20 - 2:55 Gery d'Ydewalle
3:05 - 3:25 Break
3:25 - 3:55 Mary Hegarty
4:05 - 4:35 Patrick Carroll
4:45 - 5:15 Susan Duffy

EYE MOVEMENTS AND VISUAL COGNITION

SECTION 1: PROGRAMMING SACCADDES

Chapters:

John Findlay, University of Durham

Burkhart Fischer, University of Freiburg

Ray Klein, Dalhousie University

Richard Abrams, Washington University

Discussant:

Anne Sereno, Harvard University

Programming of Stimulus Elicited Saccadic Eye Movements

John M. Findlay

The saccadic eye movement to a target which appears suddenly in the peripheral visual field is an automatic response and has been the subject of many studies. This paper reviews these studies and explores their relevance for understanding more centrally programmed saccades. Saccades are often held to be stereotyped and ballistic. While neither characterization holds absolutely, for most purposes it is adequate to specify a saccade by its vector amplitude and its time of initiation.

There is considerable evidence that the spatial signal for target-elicited saccades uses a form of neural population coding which involves integration over extensive regions of visual space. One consequence appears in studies of saccades to double targets and to extended targets. Such saccades are directed to the center of gravity of the target configuration. Recent work links this effect with psychophysical studies of the processing of information in early vision. More global information appears to be processed more rapidly and edges are particularly emphasized. The spatial framework in which the programming is carried out is still a matter of some debate since recent work casts doubt on some of the earlier demonstrations of programming within a head-centered framework.

Numerous factors influence the latency with which a target-elicited saccade is made. The visual characteristics of the target generally do not exert a large effect, in contrast to factors relating to its temporal predictability. Situations involving highly predictable targets have been reported to give rise to a separate population of saccades - the express saccades. However the circumstances in which such a separation occurs may be rather limited.

It may readily be demonstrated, particularly using the double target paradigm, that target-elicited saccades can be modified by prior instructions, etc. This plasticity provides a way to explore the relationship between stimulus factors and cognitive factors: one promising route links studies of saccadic eye movements with those of covert attentional processes.

Saccadic Reaction Time: A Study of No Eye Movements

Burkhardt Fischer

The natural pattern of human eye movements consists of periods of eye rest (fixations) interrupted by rapid movements (saccades). The time before a saccade, the "last fixation", contains the history of a saccade and is full of different periods corresponding to different neural actions of several brain structures involved in vision, visual cognition, and in the generation of the saccade itself. We have analyzed this time period in man and in monkey by measuring the influence of several - physical and psychological - parameters on the saccadic reaction time. Among them are: the dissociation of the location of the target and the location to which the saccade is being directed; the significance of the fixation point; the direction of attention. Manipulating these parameters may change the saccadic reaction times by more than a hundred milliseconds, from express saccades (100 ms, 70 ms) to slow regular saccades (220 ms, 190 ms; man, monkey). The analysis of the data reveals that in many cases the distribution of saccadic reaction times exhibits two or more modes reflecting different time consuming processes that take place while the eye is not moving. A special experiment utilizing isoluminant pure color contrast stimuli together with lesion studies help to identify the anatomical and physiological structures that are involved in the coordination of vision and eye movements. Additional information from single cortical and subcortical cells in the monkey result in a concept that provides a possible understanding of the relationship between attention, fixation, eye rest, and the programming of saccades. The concept may be applied to understand the basic process of reading and its related deficits, e.g. dyslexia.

Orienting and Visual Attention

Ray Klein

Perception of any visual scene or display can be spatially selective in two senses. First, overt adjustments of gaze direction can be made to control which regions of the visual field are processed by the sensitive fovea and its associated neural machinery. Second, covert adjustments can be made to determine which specific objects are selected (in the absence of gaze changes) for preferential treatment. Overt and covert visual orienting can be controlled exogenously by features of the visual scene and endogenously by the observer's expectations and intentions. Imagine the 2x2 matrix implied by this classification. Our recent and ongoing research on visual orienting has been aimed at achieving a better understanding of the individual cells of this matrix, as well as of the inter-relationships among the cells. Some of our research projects will be presented to illustrate our questions, methods, and findings in the area of visual orienting.

Planning and Producing Saccadic Eye Movements

Richard A. Abrams

Research from a number of different paradigms can provide insight into details of the psychological mechanisms underlying the planning and production of saccadic eye movements. Several studies are discussed in which subjects produced saccades to visible targets that either remained fixed in space, or changed their position immediately prior to or during the saccade. Saccade amplitudes and latencies, and kinematic features of the saccade trajectories were evaluated. Results indicate that people prepare saccades by making individual decisions about parameters such as the direction and amplitude of the eye movement needed to reach the target. Decisions about direction appear to be made before those about amplitude in many, but not all, situations. In addition, decisions about amplitude require the specification of two parameters: (a) a force parameter which specifies the magnitude of the force pulse applied to the eye, and (b) a time parameter which determines the duration of the pulse. Variability in the force and time parameters leads to a linear tradeoff between the average velocity of saccades and the standard deviation of their spatial endpoints, and conforms to a model initially developed to describe aimed limb movements, suggesting that common principles may underlie the production of both eye and limb movements. Analysis of kinematic features of saccades shows that the force and time parameters usually covary (with larger saccades requiring larger forces and longer duration force pulses), although they can sometimes be separately modulated. In particular, when the retinal feedback available after a saccade is distorted over a series of movements, subjects adjust the magnitude of the force pulse (force parameter) but the duration of the pulse (time parameter) remains relatively constant. Finally, parameters for an upcoming saccade can be modified shortly before the saccade is initiated. This modification sometimes requires additional time depending on the aspect of the movement being changed. Taken together, the results have implication for the processes involved in preparing and producing saccades used to scan visual scenes.

SECTION 2: VISUAL SEARCH AND INTEGRATION

Chapters:

Wolfgang Prinz, University of Munich

Mary Hayhoe, University of Rochester

David Irwin, Michigan State University

Sandy Pollatsek, U of Massachusetts

Discussant:

Don Fisher, University of Massachusetts

Global, Local, and Moment-to-Moment Control of Eye Movements - Evidence from Continuous Visual Search

Wolfgang Prinz, Thomas Ullman, and Dieter Nattkemper

Some controversy has centered around the issue of the relationship between the ongoing information processing activities in visual tasks and the temporal (fixation time) and spatial (saccade size) decisions of the eye movement control system. We address this issue with respect to the continuous visual search task.

Regarding the level of control, two types of models are distinguished, global and local control. Global control models assume the control of temporal and spatial parameters of eye movements to be almost entirely independent from the ongoing cognitive activities. Under local control, the decisions of the eye movement control system are supposed to be fairly closely linked to the ongoing information processing.

The empirical evidence available from the continuous visual search task seems to rule out global control since we observed a different within-trial development of eye movement patterns in scanning random and redundant search lists. Furthermore, there are at least three pieces of evidence demonstrating an influence of local stimulus and information processing characteristics on eye movement parameters. They come from (i) studies of the correlation between saccade amplitudes and fixation durations, (ii) from an analysis of the functional basis for regressive eye movements, and (iii) from data analyzed in order to study the mechanisms underlying the detection of targets in search.

These data clearly demonstrate that both fixation durations and saccade amplitudes vary with local stimulus and information processing characteristics. This raises the further issue of whether or not these local variations are examples of moment-to-moment control of eye movements. Under moment-to-moment control the decisions of the control system are so closely linked to the ongoing processing that the temporal and spatial parameters of eye movements are controlled within individual fixations.

We address this issue in two experiments where processing demands were manipulated within search lists. The critical question was whether one would observe immediate or delayed adjustments of the temporal and/or spatial parameters of the eyes scanning pattern to variations in processing demands. Immediate effects would speak in favor of moment-to-moment control whereas delayed effects would suggest that control is shifted to a level where distribution parameters of fixation durations and saccade amplitudes are fixed for some time according to the processing demands encountered in previous fixations (or at least one prior fixation).

Spatial Memory and its Role in Integrating Information Across Successive Views

Mary Hayhoe

To perceive a stable world, we must be able to relate visual information from successive fixations, and it has often been assumed that the perceptual system constructs a representation of a scene that is integrated across successive fixations. Little is known, however, about the nature of the integrative processes. One explicit suggestion in the literature is that retinotopic images are added together in an extended image whose co-ordinate system is fixed to positions in the world. However, numerous attempts to show some "fusion" or addition of images from different fixations have been unsuccessful, and this has cast doubt on the existence of an integrative process and an extended global image. What, then, is the nature of the visual information which is retained from prior views? Many of the previous investigations have looked for an enhancement of visual viewing processing of the current foveal image by the peripheral stimulus that preceded a saccade to that spatial location. However, the aspects of our perceptual experience which led to the assumption that an integrative process must exist do not require this sort of enhancement, but rather the building of a representation that combines information from prior foveal views to produce a more complete scene description than is available from a single view. In this experiment we asked how well a simple shape judgment can be made when only part of the shape information is available in a single fixation. If such a task can be performed relatively easily, then the spatial information retained from previous views must be quite precise. In addition, good performance would point towards an integrative process that operates on pre-categorical information, since in this task the form emerges only in the integrated representation. The particular task we chose was an angle judgment. Subjects were presented with 3 points in succession, which defined a triangle. Subjects tried to judge whether the top angle in the triangle defined by the time-integrated view was a right angle. We measured the precision with which subjects can make these judgments both when the eyes were stationary and when they moved between the dot presentation. Subjects performed the task with little difficulty and were able to make fairly fine spatial form judgments over quite long time intervals, independent of eye position. When a stationary reference point was visible, it made little difference whether or not Ss moved their eyes. Without a reference point, Ss must use eye position information to compute the location of the dots. In this case performance was somewhat worse.

These results indicate that Ss are using an underlying spatial representation that allows them to integrate precise spatial information in a frame fixed to positions in the world. The precision of the spatial position information points towards a map-like, or spatially ordered representation precise enough to support geometrical judgments. While it is hard to make definitive conclusions from a single experiment of this sort, the perceptual memory revealed here is not well described as "semantic" or "propositional". On the basis of these data it seems more likely that the integration is performed at

Mary Hayhoe (continued)

some intermediate level of visual representation.

Our results also have implications for the mechanisms of visual stability. It is most commonly thought that successive views are aligned using an eye position signal. However, the results of the present experiment clearly indicate a visual matching strategy in relating successive views, since subjects do better when successive frames can be aligned with respect to the fixed reference point. This suggests that the visual reference information is used to refine eye position information, and that spatial locations of objects in successive frames are assigned with respect to objects common to the frames. I will also discuss results we have obtained in experiments examining saccades to remembered locations, which provide additional support for the role of visual reference frames in encoding spatial position.

Properties of Transsaccadic Integration

David E. Irwin

The visual world contains more information than can be perceived in a single glance. Consequently, humans make eye and head movements and somehow construct a stable and continuous representation of the visual environment from these successive views. How this is accomplished has puzzled psychologists for over a century. The present paper discusses the properties of transsaccadic integration, the integration of information across saccadic eye movements.

One frequently proposed hypothesis about transsaccadic integration is that the visible contents of successive fixations are superimposed and fused in memory according to environmental coordinates. This hypothesis, though intuitively appealing, appears to be incorrect: Subjects are unable to integrate two different visual patterns presented in the same spatial location but viewed in separate fixations in order to perceive a composite pattern. Furthermore, one's ability to detect a stimulus presented after an eye movement is unaffected by a prior presentation of the same stimulus in the same place in space before the eye movement. Taken together, these results suggest that transsaccadic integration does not operate via an environmentally-coded fusion of visual information across eye movements.

An alternative conception of transsaccadic integration holds that integration occurs at a more abstract level, through the accumulation of schematic visual codes acquired during successive fixations. This hypothesis is supported by the finding that subjects can accurately determine whether two random-dot patterns viewed in successive fixations are identical or different; this is so even when the two patterns appear in different spatial positions across the saccade. Subjects' recognition accuracy is greatly influenced by pattern complexity, but interpattern interval has very little effect on performance, even when a 5-second interval separates the two patterns. These results indicate that transsaccadic integration relies on a limited-capacity, long-lasting memory that is not tied to absolute spatial position, rather than on a high-capacity memory that summates individual fixations based on environmental coordinates. In addition, this memory appears to code the relative positions of objects in the world defined with respect to one another, rather than the absolute positions of objects in space.

These properties of transsaccadic integration suggest that perceptual stability across eye movements may result largely because the relative spatial positions of objects in the world typically don't change across changes in eye position. In addition, the limited-capacity nature of transsaccadic memory implies that many environmental changes during eye movements might go undetected. It appears that the mental representation of the environment that is constructed across eye movements is surprisingly schematic and undetailed, and based more on the contents of the current fixation than on one's memory for the contents of previous fixations.

Integration of Information Across Saccades in Reading and Picture Perception

Alexander Pollatsek and Keith Rayner

Perception in the real world is usually interrupted by a series of saccades, occurring roughly four times a second. In spite of this, perception appears to be stable and information is integrated somehow across the fixations between these saccades. A large body of research has attempted to determine how information is integrated across saccades in reading. While the details of how this is done are far from clear, certain general facts have emerged. Perhaps the most surprising is that visual information at the level of "features" (e.g., something like Marr's "primal visual sketch") is not preserved and that the level at which something is preserved is more abstract. Recent research indicates that in reading, codes relating to both the phonological representation and the abstract letter representation are integrated across saccades. However, there is no evidence of either morphemic or semantic information being used in the integration process. For pictures, the findings are a bit different. There, it appears that something about the visual form of the object is maintained over the saccade that is relevant in identifying the object on the next fixation. However, it is possible that the process of integration works in fundamentally the same way in picture perception as in reading.

SECTION 3: SCENE PERCEPTION

Chapters:

Geoffrey Loftus, U of Washington

Susan Boyce, AT&T

Peter DeGraef, University of Louvain

John Henderson, University of Alberta

Discussant:

Judith Kroll, Mount Holyoke College

Why it's Annoying to Watch Slides with the Room Lights still on:
Effects of Stimulus Degradation on Visual
Information Processing

Geoffrey Loftus

We have all had the experience of trying to read a photocopy of a photocopy, or trying to watch slides with the room lights still on. We know that it is more difficult to see and comprehend such degraded stimuli relative to normal, or clean stimuli. Why is this? I will describe three sets of experiments dealing with various aspects of perceiving and remembering degraded visual stimuli.

In the first set (actually, a single experiment), we found that eye fixation durations increased when naturalistic pictures were degraded by reducing contrast. This finding raised two questions addressed by the remainder of the experiments. First, does degradation slow down early perceptual processing? Second, does degradation have any effect on a stimulus's long-term memory representation apart from any effect mediated by degradation's influence on early perceptual processes?

These two questions were embodied in two corresponding hypotheses which we refer to as the slowdown hypothesis and the single-dimension hypothesis. In the experiments to test these hypotheses, we probed memory for pictures that had been shown at different durations and in either a clean or a degraded state. The data from this paradigm assume the form of performance curves which relate memory performance to stimulus duration. Comparisons of performance curves corresponding to clean and degraded stimuli allowed evaluation of the hypotheses.

The second set of experiments tested the slowdown hypothesis, which is: degradation causes a quantitative slowing, by some factor k , of early perceptual processes. The slowdown hypothesis makes a prediction about performance curves from clean and degraded stimuli that takes the form of the following equation:

$$P(\text{degraded}, kd) = P(\text{clean}, d)$$

Here P is performance, d is stimuli duration, and k is a constant, the slowdown hypothesis predicts it to require k times as long to achieve the same performance level for degraded relative to clean stimuli. The hypothesis was confirmed for two quite different kinds of visual stimuli (digit arrays and complex pictures).

The third set of experiments tested the single-dimension hypothesis, which is: the influences of stimulus duration and stimulus degradation are combined by perceptual processes to produce, as part of the early memory representation, a single number on a unidimensional scale. The hypothesis thus implies that information about a stimulus's degradational state is lost at an early processing stage and is thus not represented in memory. The hypothesis was tested in several ways and was confirmed in three experiments, but disconfirmed in a fourth. Results of an additional experiment suggested that failure of the single-dimension hypothesis (and, as it turns out, of the slowdown hypothesis as well) may occur when a stimulus's degradational state is consciously encoded as part of the memory representation.

The Identification of Objects in Scenes:
The Role of Scene Backgrounds in Objects Naming

Susan J. Boyce and Alexander Pollatsek

Prior research with scenes has indicated that scene context facilitates object identification. The evidence comes from two types of paradigms. In one, scenes are presented for less than 200 ms followed by a mask, and accuracy of reporting the presence or absence of a target object is the primary dependent variable. In the other, scenes are presented for free viewing, and the time to fixate key objects in the scene is measured. The former paradigm may be unrepresentative of normal object identification, since the scenes are briefly presented and the objects are not fixated. The latter may not be measuring object identification, since fixation times may reflect post-identification processes (especially since memory tasks are standardly employed).

We will discuss results obtained from a new paradigm in which an object in a scene is "wiggled" -- drawing both attention and an fixation to itself -- and then named. Thus, scene context effects can be examined in a situation where the target object is fixated and fully visible, but where the measure (naming time) is more likely not to reflect unwanted post-identification effects. Experiment 1 indicated that a background that was semantically consistent with a target object facilitated the speed of naming. A second advance of this paradigm is that the time course of processing can be examined using display changes contingent on eye movements. Experiments 2 and 3 factorially varied whether a meaningful background was present on the first fixation (in the center of the display) or on the second fixation (on the target object). Although the results from Experiment 2 were inconclusive, Experiment 3 demonstrated that scene background information present only on either the first and second fixations on a scene significantly affects naming time. Thus, background information appears to be extracted immediately from scenes and appears to be extracted continuously from scenes even when objects are fixated, rather than on just the first fixation.

We will discuss the implications of these results both methodologically and for models of scene processing.

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Perceptual Effects of Scene Context
on Object Identification

Peter De Graef, D. Christiaens, and Gery d'Ydewalle

In a number studies, the context provided by a real-world scene has been claimed to have a mandatory, perceptual effect on the identification of individual objects in such a scene. This claim has provided a basis for challenging widely accepted data-driven models of visual perception in order to advocate alternative models with an outspoken top-down character. The present paper, however, offers a careful review of the evidence in order to demonstrate that the observed scene context effects may be the product of post-perceptual and task-dependent guessing strategies. A new research paradigm providing an on-line measure of genuine perceptual effects of context on object identification is proposed. First fixation durations for objects incidentally fixated during the free exploration of real-world scenes, are shown to increase when the objects are impossible in the scene or violate certain aspects of their typical spatial appearance in the scene. These effects of contextual violations are demonstrated to emerge only in later stages of scene exploration, arguing against the notion of schema-driven perception effective from the very first scene fixation on. In addition, evidence is reported in support of the existence of a facilitatory component in scene context effects. This is taken to indicate that context directly affects ease of perceptual object processing and does not merely serve as a framework for checking the plausibility of the output of perceptual processes. Finally, our findings are compared with other, contrasting results and some future research questions are highlighted.

Visual Attention and Eye Movement Control During Reading and Scene Perception

John M. Henderson

Experimental psychologists have recently amassed a great deal of evidence supporting the hypothesis that the visual system can select a particular location over other locations in the visual field for further analysis without overtly orienting the eyes to the selected location. At the same time, we know that during reading and scene perception, the eyes are overtly directed to new regions of the visual field every 200 to 300 msec on average. How are covert shifts of attention and overt movements of the eyes related during complex visual-cognitive tasks? In this paper I will review past studies and present a tentative model of the relationship between attention and eye movements. The Sequential Attention Model embodies two main assumptions: (1) There is generally a time-locked relationship between the allocation of attention and shifts of eye position, so that visual attention precedes the eyes to a particular location by a constant amount of time, and (2) There is a tendency on the part of the eye movement control system to keep the eyes in motion, so that when foveal processing is difficult, the signal to move the eyes may be generated before attention is re-allocated away from the fovea. These two assumptions allow the model to account for a great deal of visual information acquisition and eye movement behavior observed in reading and scene perception.

SECTION 4: READING

Chapters:

George McConkie, University of Illinois

Sara Sereno, University of Massachusetts

Robin Morris, U of South Carolina

Kevin O'Regan, U Rene Descartes

Albrecht Inhoff, SUNY, Binghamton

Discussant:

Rene Schmauder, U of Massachusetts

Vision and Cognition in Reading: The Meeting Point

George W. McConkie and Paul Kerr

We examine the effects of text stimulus manipulations on the frequency distributions of the durations of eye fixations. There appear to be two categories of effects, those that occur consistently at a specific time after the onset of a fixation, and those that can occur at any time following a certain point in the fixation. We suggest that the first results from an interrupt produced in automatic processes that make visually-provided information available for use. The second results from problems encountered by the higher cognitive processes when they attempt to put the available information to use for the purposes of the current task, in this case, is reading. Thus, the way that a stimulus manipulation changes the shape of the frequency distribution of fixation durations may help indicate where in the processing an effect is occurring. The paper will end by discussing the possible locus of the meeting point between the automatic, visually-induced processes and the higher language processes during fixations in reading.

Early Lexical Effects when Fixating a Word in Reading

Sara C. Sereno

This paper will deal with the limits of information that can be obtained when a word is first fixated in reading. Two different studies will be described. The first study deals with a comparison of the first fixation of words fixated only once versus words fixated twice. It also compares the first and second fixations of a refixated word. One primary finding was that there were word frequency effects in the first fixation durations. It was also found that the duration of the first fixation (when words are refixated) is shorter than the second fixation. The data suggest that a common attentional mechanism underlies the effects.

In the second study, near-threshold primes were "flashed" in a target location prior to the onset of a target word while subjects read. The type of prime (related, unrelated) and the duration of the prime (20-60 ms) were manipulated. Fixation times on the target revealed significant priming from 30 ms prime exposures.

Using Eye Movements to Assess the Effects of Sentence Context on Word Processing During Reading

Robin K. Morris

Numerous studies using a variety of methodologies have demonstrated that the context in which a word occurs can influence the processing of that word. The experiments can be broken down into two categories; 1) those that attempt to determine the stage(s) of word processing that are vulnerable to sentence context effects (i.e., visual encoding, lexical access, text integration) and 2) those that deal with the characteristics of the sentence context that are responsible for the effect (predictability, lexical primes, the integrated text representation). Recent eye movement studies that illustrate the need to consider both of these issues when evaluating the effect of sentence context on word processing during reading and the advantages of using an on-line measure, such as fixation time will be presented.

In one such study, subjects eye movements were monitored as they read sentences presented on a CRT. Processing time on an unambiguous target noun was evaluated as a function of the context in which it occurred. Converging evidence from a naming time experiment was drawn upon to determine the stage of word processing that was affected. Lexical, syntactic, and message-level factors in the preceding sentence context were systematically varied to evaluate the extent to which different components of the language processing system could influence word processing. Evidence that lexical access is sensitive to integrated sentence level representations was found. Implications for current theories of language processing in reading will be discussed.

Optimal Viewing Position in Words and the "Strategy-Tactics" Theory of Eye Movements in Reading

J. Kevin O'Regan

Up until about five years ago, the work in my laboratory was motivated by the idea that the notion of "perceptual span" was vital in understanding where the eye goes at each saccade in reading. However the results of an experiment we did cast doubt on the idea.

Fortunately the discovery of the "optimal viewing position phenomenon" came to our rescue: The time it takes to recognize an isolated word depends very strongly on the position where the eye initially lands in the word. There is an "optimal viewing position" where recognition is fastest. For each letter that the eye deviates from this optimal position, recognition time increases by 20 ms. The location of the optimal position is often near a word's middle, but lexical factors may modify this.

We are now trying to test to what extent the optimal viewing position phenomenon may be important in understanding the way the eye behaves in normal reading. I shall present an extreme hypothesis, the "strategy-tactics" theory, which makes precise predictions about the eye's moment-to-moment behavior. I shall then attempt to evaluate the hypothesis in the light of past work and recent experiments.

Oculomotor Control in Reading and Copytyping

Aibrecht Inhoff, Gregory Bohemier, and Deborah Briihl

Oculomotor movements are used to obtain effective visual information in different task environments. The current chapter examines how two different uses of visual input affect oculomotor control. In reading, visual text is used to build a linguistic representation which codes semantic and pragmatic aspects of encoded text. The same visual information can be used to program a sequence of to-be-executed manual keystrokes in a copytyping task. Examination of eye fixations and of saccade size in the two tasks shows major differences. Relatively short fixation durations are much more prevalent during copytyping than during reading, indicating that typists may program more than one saccade during fixation durations in copytyping. Furthermore, typists obtain effective visual information across a relatively small spatial area, which may be related to the short duration of the corresponding fixation durations and the planning of multiple saccades.

SECTION 5: READING AND PICTURES

Chapters:

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The Spatial Coding Hypothesis

Alan Kennedy

An obvious distinction between speech and writing, as representational systems, relates to their permanence. Speech is processed under conditions where the stimulus is no longer present. In contrast, printed text typically remains available as a visible object. The widely-accepted claim that linguistic control is exerted over eye movements during reading in fact rests on relatively unexplored assumptions concerning the spatial representation of text. This paper examines the concept of "spatial coding" and discusses it in the context of the proposition that locative information may be used by the skilled reader in a number of psycholinguistics processes.

The Nature of the Co-Ordinate System. Our internal representation of the visual world is glued together from a set of foveal snapshots in which the temporal and spatial are effectively decoupled. However, in so far as an alphabetic script can be seen as a means to recovering speech (i.e. a representational system in which there is a necessary temporal order), the reader must derive both spatial and temporal representations. The paper considers, and dismisses, claims that eye movement control is not spatially guided. Since locative knowledge can only exist in a particular coordinate system it is necessary to consider the level of representation employed by the reader. Using the taxonomy proposed by Wade and Swanston it is proposed that control over eye movements during reading cannot take place in either a retinocentric or orbitocentric frame of reference. Less obviously, the claim is advanced that control is not geocentric (sometimes referred to as "viewer-centered"). Rather, it makes use of relational information (what Wade and Swanston refer to as the patterncentric level of representation).

The Tokens of Spatial Representation. In proposing a "spatially-addressed" memory it is necessary to consider what its contents are: What do the pointers in such a coding system point to? For example, systematic reinspections of words in text may be triggered by anaphoric reference or systactic ambiguity; but why, in relatively short sentences, should the reader examine the same word twice? Two tentative answers are proposed: (1) the most efficient route to the lexicon may be via the (mandatory) stimulus-driven processes inherent in visual inspection; (2) attention and visual inspection are obviously inter-related - reinspection may not be to a word but to a place where some particular cognitive operation took place.

Spatial Cues to Word Order - Reanalysis and Reinspection. A link between the mechanisms which control visual reinspection and the cognitive operations of reanalysis has been assumed in the psycholinguistic literature. However, reinspection itself demands psychological explanation in terms of the representations preserved by the reader which allows for its operation. The paper examines the role played by "Spatialization" as a cue to word-order and examines some recent experimental evidence suggesting that modes of presentation which do not permit differential spatial coding of words in text disrupt syntactic analyses when word-order information is crucial.

Tracing the Course of Sentence Comprehension:
How Thematic Role Information is Used

Charles Clifton, Jr.

Eyetracking methodology has played a pivotal role in the recent development of the psycholinguistics of sentence comprehension. Its ability to illuminate the early stages of reading has fueled the development of theories that emphasize the role of specialized, automatic processes for assigning grammatical structure to sentences. In several cases, the methodology has provided evidence that extra-grammatical knowledge-based processes do not guide the initial analysis of sentences, as they have sometimes been claimed to do. Instead, such knowledge-based processes seem to evaluate and correct analyses that are initially constructed on the basis of syntax alone.

This claim will be illustrated with a series of three eyetracking experiments that follow up results reported by Laurie Stowe (in Carlson and Tanenhaus, Linguistic Structure in Language Processing, 1989). Stowe reported slow self-paced reading time for the disambiguating verb fell in sentences like (1a), with an animate subject, but not in sentences like (1b), with

(1a) As the children rolled the ball fell off the table.

(1b) As the pennies rolled the ball fell off the table.

an inanimate subject. This result suggests that thematic role preferences guide sentence analysis. Ergative verbs, such as roll, are analyzed as taking either an AGENT or a THEME as subject, and animate NPs are presumed to be preferred AGENTS while inanimate NPs are preferred THEMES. A reader following these preferences will take the ball to be object (and THEME) of (1a), but not of (1b), and will therefore be garden-pathed only in (1a).

The experiments to be reported used a variety of measures of eye movement to show that Stowe's conclusions hold only for measures sensitive to relatively late-operating factors. Measures sensitive to early processing effects indicated that readers initially take the postverbal NP to be direct object, regardless of animacy of the subject. However, the experiments differed in which measures reflected which factors, suggesting the need for further analysis of eyetracking methodology.

Attention Allocation with Overlapping Sound, Image, and Text

Gery d'Ydewalle

A television program has at least two channels of information: A visual one (the image) and an auditory one (the sound). Moreover, television programs in some countries are often imported and subtitled in the native languages of the viewers. The subtitles, then, are a third source of information. Each of the three sources of information are partly redundant: They don't contradict but rather supplement one another, or express the same content yet in a different form. Our studies suggest that switching the attention between the different channels of information is an effortless process: Reading the subtitles is more or less compulsory, and there seems to be no trade-off with the processing of the other sources. Although the mandatory reading of the subtitles develops quickly with reading acquisition in school, it can not be considered as a purely automatically elicited type of behavior. As a function of interest and involvement, information in the image, and the necessity to read the subtitles for understanding the movie, viewers flexibly allocate their attention between the image, the sound track, and the subtitles.

The Mechanics of Understanding and Understanding Mechanics

Mary Hegarty

When people attempt to understand machines by reading text accompanied by diagrams, they must comprehend the text and diagrams separately, and integrate information from the two media. One focus of this paper is the process of inferring system kinematics from a static diagram. Reaction time and eye-fixation data indicate that this process involves mentally stepping through the kinematic chain of events from the input of the machine to infer the kinematics of successive components.

Another focus of the paper is how people coordinate the intake of information from a text and diagram and so construct a mental model of a mechanical system. Eye-fixation and comprehension data indicate that the coordination process is largely text directed. However, individuals with high mechanical ability encode information more easily from either a text or a diagram, whereas low-ability subjects are more dependent on the text to direct their processing of the diagram.

Visual Analysis of Cartoons: A View from the Far Side

Patrick Carroll, Jason Young, and Michael Guertin

Captioned cartoons are a simple example of stimuli that require people to integrate information represented in the stimulus in two forms, linguistic and pictorial. Skilled cartoonists can create stimuli that are both simple and interesting, and the integration task is one that is intrinsically compelling. Eye movements were recorded as subjects viewed a series of cartoons. Captions and pictures were displayed separately with the caption either preceding or following the picture. The subjects' task was to comprehend the cartoon, an event highly correlated with the "snort effect" that occurs when a person tries to chuckle on a chin rest. After viewing all 24 cartoons, subjects were again shown the picture portions and were asked to remember the caption while having their eye movements recorded. Eye movement patterns on pictures are consistent with previous reports of fast assessment of the picture's structure and followed by cognitively constrained fixation patterns. Task differences appear to influence different scanning characteristics of picture viewing and reading patterns.